# RV SURVEY FOR PLANETS OF BROWN DWARFS AND VERY LOW-MASS STARS IN CHA I

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## ABSTRACT

We have carried out a radial velocity (RV) search for planets and brown dwarf companions to very young (1-10 Myr) brown dwarfs and very low-mass stars in the Cha I star forming region. This survey has been carried out with the high-resolution Echelle spectrograph UVES at the VLT. It is sensitive down to Jupiter mass planets.

Out of the twelve monitored very low-mass stars and brown dwarfs, ten have constant RVs in the presented RV survey. This hints at a small multiplicity fraction of the studied population of brown dwarfs and very low-mass stars in Cha I at small separations. Upper limits for the mass $M_2 \sin i$ of possible companions have been estimated to range between $0.1\,M_{Jup}$ and $1.5\,M_{Jup}$. However, two very low-mass stars in Cha I show significant radial velocity variations. The nature of these variations is still unclear. If caused by orbiting objects the recorded variability amplitudes would correspond to planets of the order of a few Jupiter masses.

Furthermore, as a by-product of the RV survey for companions, we have studied the kinematics of the brown dwarfs in Cha I. Precise kinematic studies of young brown dwarfs are interesting in the context of the question if brown dwarfs are formed by the recently proposed ejection scenario. We have found that the RV dispersion of brown dwarfs in Cha I is only $2.2\,\mathrm{km\,s^{-1}}$ giving a first empirical upper limit for possible ejection velocities.

Key words: extrasolar planets, brown dwarfs, planet formation, brown dwarf formation.

## 1. INTRODUCTION

Most of the extrasolar planets known to date are considerably old, with ages of the order of a few billion years. The youngest planet known to date is orbiting the zero-age main sequence star $\iota$ Hor, with an estimated age in the range of 30 Myr to 2 Gyr (Kürster et al. 2000). Furthermore, most planets known to date orbit around solar-mass stars with spectral types of late-F, G and early-K with the exception of a planet around the M4-dwarf Gl 876, which has an estimated mass of 0.3–0.4 $M_\odot$ (Delfosse et al. 1998, Marcy et al. 1998).

The search for planets around very young as well as around very low-mass stars (and even down to the substellar regime) is particularly interesting since the detection of *young* planets as well as a census of planets around stars of all spectral types, and maybe even around brown dwarfs, is an important step towards the understanding of planet formation. It would provide empirical constraints for planet formation time scales. Furthermore, it would show if planets can exist around objects which are of considerably lower mass and surface temperature than our sun.

We have therefore carried out a RV survey for (planetary and brown dwarf) companions to young brown dwarfs and very low-mass stars in the Cha I star forming region. It is aimed at the finding of young planets and brown dwarf companions with an age of a few million years around mid- to late-M dwarfs close or below the Hydrogen burning limit.

The detection of planets around brown dwarfs as well as the detection of young spectroscopic brown dwarf binaries (brown dwarf–brown dwarf pairs) would, on the other hand, be an important clue towards the formation of brown dwarfs. So far, no planet is known orbiting a brown dwarf. There have been detected several brown dwarf binaries, among them there are three spectroscopic, and hence close, brown dwarf binaries (Basri & Martín 1999, Guenther & Wuchterl 2003). However, all known brown dwarf binaries are fairly old and it is not yet established if the typical outcome of the brown dwarf formation process is a binary or multiple brown dwarf system or a single brown dwarf. Furthermore it is not known, if brown dwarfs can have planets.

## 2. SAMPLE

The targets of our RV survey are a population of 12 young bona fide and candidate brown dwarfs (spectral type M6–M8) in the center of the Cha I star forming cloud (distance ∼160 pc) with ages of 1–5 Myr. They have been detected by Comerón et al. (1999, 2000) and Neuhäuser & Comerón (1999) and are named Cha H$\alpha$1–12. Furthermore, our sample includes several young (< 10 Myr), very low-mass T Tauri stars in the region, B 34, CHXR 74 and Sz 23, which have spectral types of M2.5–M5 and masses of about 0.1–0.3 $M_\odot$ (Comerón et al. 1999).

## 3. UVES SPECTRA AND RV MEASUREMENTS

High-resolution ($\lambda/\Delta\lambda$ = 40 000) spectroscopy has been performed of the objects in the red region of the optical wavelength range (6700 Å–1 $\mu$m) with the Echelle spectrograph UVES at the 8.2 m VLT Kuyen telescope at ESO Paranal, Chile. We took several spectra, at least two, of each of the objects in 2000 and 2002. We have measured RVs with a precision of down to 40 m/s by means of cross-correlating plenty of stellar lines of the object spectra with a template spectrum using telluric lines as wavelength reference (Joergens & Guenther 2001; Joergens 2003). The RV precision of the relative RVs ranges between 40 m/s and 600 m/s depending on the S/N of the individual spectra. The RV errors have been estimated by the deviations of two consecutive RV measurements based on two single consecutive spectra.

## 4. RESULTS

### 4.1. Low multiplicity of brown dwarfs

We have found that the radial velocities for the bona fide and candidate brown dwarfs Cha H$\alpha$ 1, 2, 3, 5, 6, 7, 8 and 12 are constant within the measurements uncertainties (Fig. 1). Cha H$\alpha$ 4 shows small variations (Fig. 2), however, they do not exceed 2 $\sigma$ (Joergens et al. 2002, Joergens 2003).

We have estimated upper limits for masses of hypothetical companions $M_2 \sin i$ of these objects by assuming that the total variability amplitude was recorded. They range between 0.3 $M_{Jup}$ and 1.5 $M_{Jup}$ based on the assumption of a circular orbit and a separation of 0.1 AU between companion and primary object. Primary masses have been taken from Comerón et al. (1999, 2000).

That means, that no planet around a young brown dwarf has been found and, furthermore, also the multiplicity fraction for close binary brown dwarfs among the sample is apparently rather low. There is, of course, the possibility that present companions

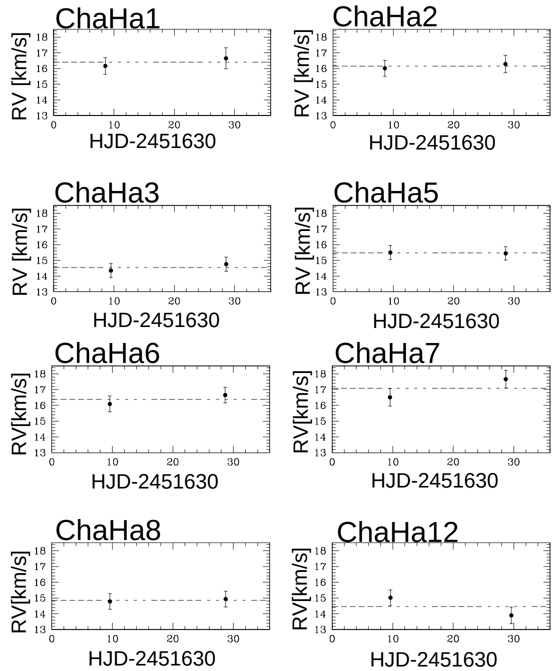


*Figure 1. RV vs. time in Julian days for bona fide and candidate brown dwarfs in Cha I based on high-resolution UVES/VLT spectra. Error bars indicate 1 $\sigma$ errors. The objects show no RV variability.*

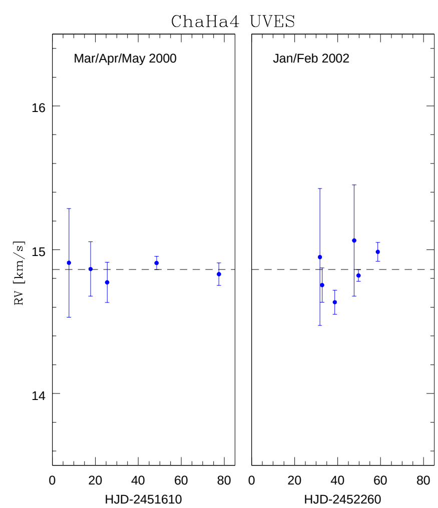


*Figure 2. RV vs. time in Julian days for the candidate brown dwarf Cha H$\alpha$ 4 based on high-resolution UVES/VLT spectra. Error bars indicate 1 $\sigma$ errors. The object shows small RV variability but not exceeding 2 $\sigma$.*

have not been detected due to non-observations at the critical orbital phases. Furthermore, long-period companions may have been missed. However, the found small multiplicity fraction of the bona fide and candidate brown dwarfs in Cha I at small separations, is also supported by the result of a direct imaging search for wide (planetary or brown dwarf) companions to the same targets, Cha H$\alpha$ 1–12, by Neuhäuser et al. (2002a, 2002b), who find a multiplicity fraction of $\leq$10%.

### 4.2. Young Jupiter mass planets ?

The RV survey of the very low-mass T Tauri stars in Cha I showed that the RVs of B 34 are constant within the measurements uncertainties, as shown in the top panel of Fig. 3. Furthermore, it revealed significant RV variations for CHXR 74 ($\sim$0.17 $M_\odot$) and Sz 23 ($\sim$0.3 $M_\odot$); cf. middle and bottom panel of Fig. 3.

The nature of these RV variations is still unclear. They could be caused by surface activity since prominent surface spots can cause RV variability due to the shifting of the photocenter while the star rotates. The other possibility is that they are caused by an orbiting mass pulling on the primary and causing a Doppler wobble. If caused by orbiting companions, the detected RV variations correspond to planets of a few Jupiter masses in close orbits around CHXR 74 and Sz 23. As an example, a hypothetical orbit has been found for CHXR 74, which matches the recorded RV data (Fig. 4). It shows that the RVs are consistent with a companion mass $M_2 \sin i$ of 2.6 $M_{\rm Jup}$ orbiting in a circular orbit with a period of 28 d. The upper limits for the rotational periods of CHXR 74 and Sz 23 are of the order of a few days based on projected rotational velocities $v \sin i$ (Joergens & Guenther 2001), i.e. a 28 d periodicity, for example, cannot be caused by rotational modulation due to surface features.

In order to explore the nature of the detected RV variations and, if caused by companions, to solve the spectroscopic orbit, follow-up observations of CHXR 74 and Sz 23 are planned. If confirmed as planetary systems, they would be unique because they would contain not only the lowest mass primaries but with an age of a few million years also the by far youngest extrasolar planets found to date giving first empirical constraints for planet formation time scales.

### 4.3. Formation of brown dwarfs: kinematics of brown dwarfs in Cha I

Brown dwarfs are an important link between the two distinct populations of planets and stars. We still do not know by which mechanism brown dwarfs form. However, we expect that the exploration of the formation mechanism producing brown dwarfs

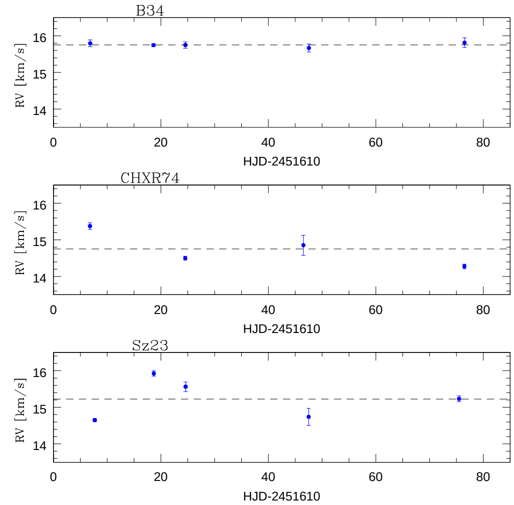


*Figure 3. RV vs. time in Julian days for the very low-mass T Tauri stars B 34, CHXR 74 and Sz 23 based on high-resolution UVES/VLT spectra. Error bars indicate 1 $\sigma$ errors. The RVs of CHXR 74 and Sz 23 are significantly variable, whereas B 34 shows no variability.*

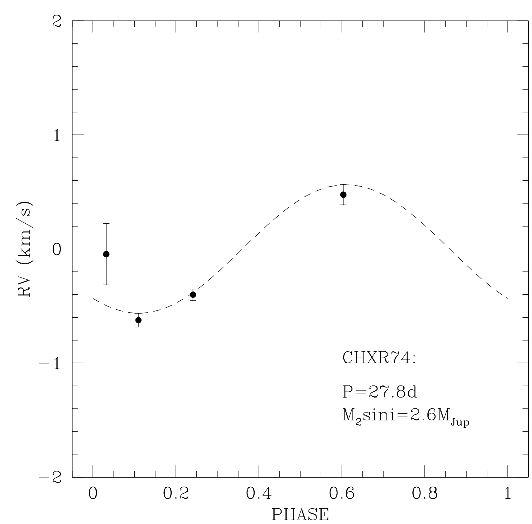


*Figure 4. Hypothetical RV curve for CHXR 74 based on the RV data shown in Fig. 3 for a planetary companion with mass $M_2 \sin i$ of 2.6 $M_{\rm Jup}$ in a circular 28 day orbit. The first data point is off by less than 1.5 $\sigma$. However, follow-up observations have to explore the nature of the detected RV variatons.*

may shed light also on some details of the planet formation. Recently, it has been proposed that brown dwarfs are formed due to the ejection of protostars in the early accretion phase, which are thenceforward cut off from the gas reservoir and cannot accrete to stellar masses (Reipurth & Clarke 2001).

Based on mean RVs derived within the presented RV survey, we have carried out a precise kinematic study of the bona fide and candidate brown dwarfs in Cha I. It showed that the RV dispersion of the brown dwarfs is relatively small, $2.2\,\mathrm{km\,s^{-1}}$, and that the RVs cover a total range of only $2.6\,\mathrm{km\,s^{-1}}$, indicating that none of the studied brown dwarfs has been ejected with higher velocity out of their birth place (Joergens & Guenther 2001). The RV dispersion of the brown dwarfs is significantly smaller than that of the T Tauri stars in the same field ($3.6\,\mathrm{km\,s^{-1}}$) and slightly larger than that of the surrounding molecular gas ($1.2\,\mathrm{km\,s^{-1}}$).

Very recent dynamical calculations (Sterzik & Durisen 2002; Bate et al. 2003) yield rather small ejection velocities for brown dwarfs, suggesting the possibility that the imprint of the ejection in the kinematics might not be an observable effect. However, these theoretical values for ejection velocities of brown dwarfs rely on certain model assumptions and are still a matter of debate. On the other side, the kinematic study presented by us contributes a first observational constraint for the velocity distribution of a homogenous group of closely confined very young brown dwarfs and therefore an *empirical* upper limit for possible ejection velocities.

## ACKNOWLEDGMENTS

We are very grateful to Eike Guenther for significant help with the spectroscopic observations and data analysis. Furthermore, we also like to thank Fernando Comerón and Matilde Fernandéz for fruitful collaborations.

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